



FAME's Science Operation Center: Concept of Operations Study

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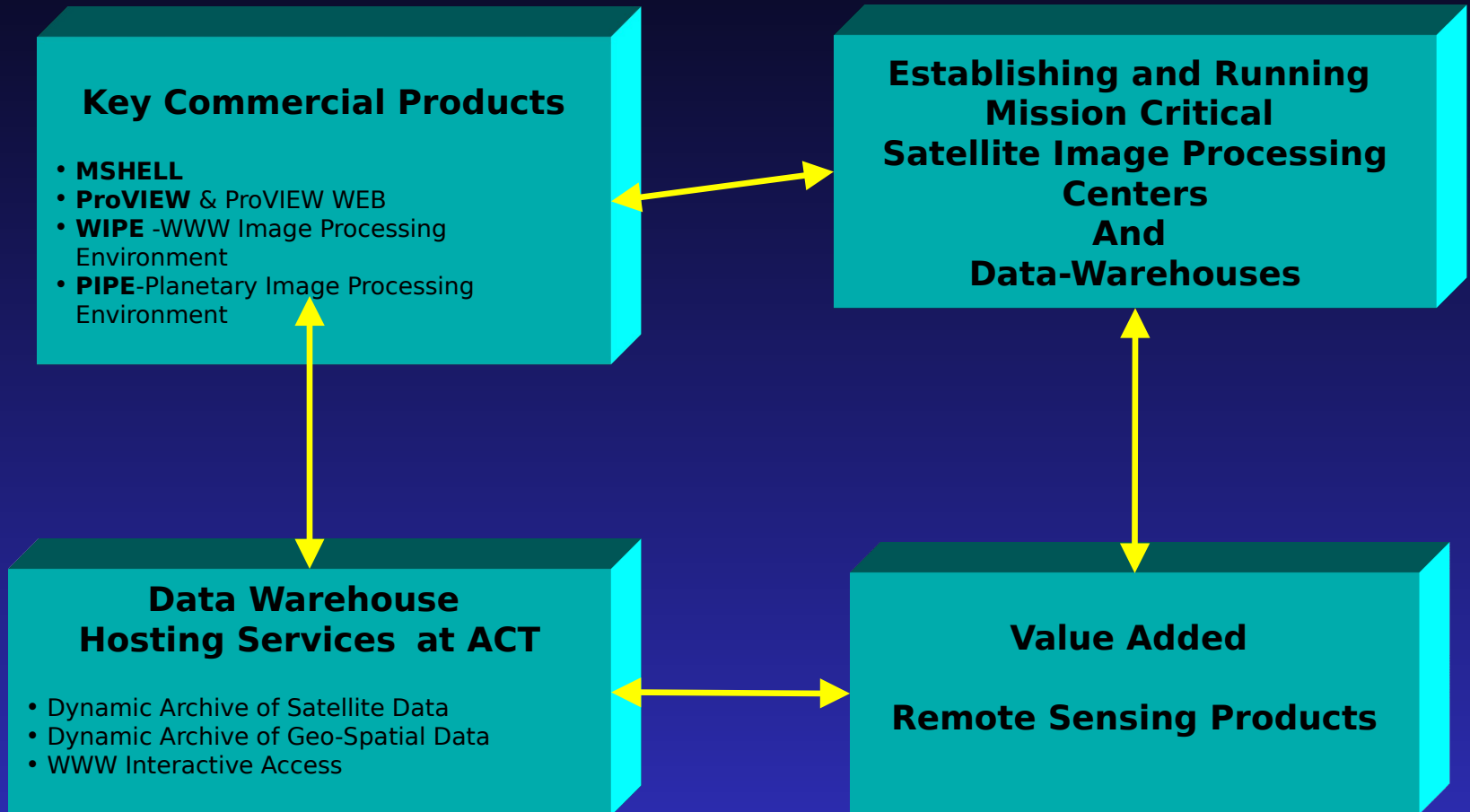
Why Is ACT Doing a SOC CONOPS Study?



- ACT Experience
 - Direct Mission-OPS Involvement
 - 8 Satellite Projects over the last 11 years
 - Four of Them under NRL/NCST
 - Implementation of Cost Effective 'PIPELINES'
 - Direct Involvement in Data Analysis Efforts
 - NAVY & NOAA Mission Critical Efforts
 - Typical Data Handling- 30-100 GBytes/day



ACT - Key Business Areas



Serving Your Data Assimilation, Processing, and Distribution Needs

MO & DA



MOPS Critical Experience

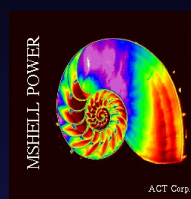
	LACE/ UVPI	Clementine I	MSTI-2 & MSTI-3	NATO's Rapid Environ. Assessment	NASA's Stardust	NOAA's Coast Watch	NAVO	NRL's NEMO (2001)	JHU/APL Messenger (2003)
Quick Look	Y	Y	Y	Y	Y	Y	Y	Y	Y
Geometry Computations	N	Y	Y	Y	Y	Y	N	Y	Y
Long Term Archival	Y	Y	Y	Y	Y	Y	N	Y	Y
In-flight Calibration	Y	Y	Y	N/A	Y	NO	N	Y	Y
Image Header Type(s)	FITS	PDS	PDS	PDS	PDS	N/A	MEDAL, SHP, ...	PDS	PDS
Level 1 Revised	N/A	<3 Months	N/A	N/A	<2months	N/A	N	2 hours	6 months
Level 2 Turn Around	6 months	N/A	<24hrs	N/A	<2months	Minutes	N	24 hours	<1hr
Level 3 (VAP) Turn Around	6 months	1 week	N/A	Interactive	N/A	Interactive	Interactive	Interactive	Interactive
WWW Access	N/A	Y	Y	Y	N/A	Y	Y	Y	Y
Approx. #of Images	500,000	2 Million	10,000 /day	Multiple Satellites Obs./day	TBD	100/day	100 images/day	40 images/day (105Gbytes)	Mercury Global Coverage
User Community	DOD	DOD/ NASA	DOD	US NAVY & NATO	NASA	NOAA CoastGuard	NAVY's Warfighter	DOD & Commercial	NASA
Key Software Used	MSHELL	MSHELL/ ProVIEW	MSHELL ProVIEW	MSHELL/ ProVIEW/ WIPE	MSHELL/ ProVIEW	MSHELL/ ProVIEW/ WIPE	MSHELL/ ProVIEW/ WIPE	MSHELL/ ProVIEW/ WIPE	PIPE ProVIEW MSHELL



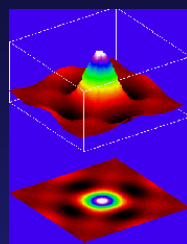
ACT's Software has have been extensively used in multiple mission critical operations



ACT Proven MOPS Software



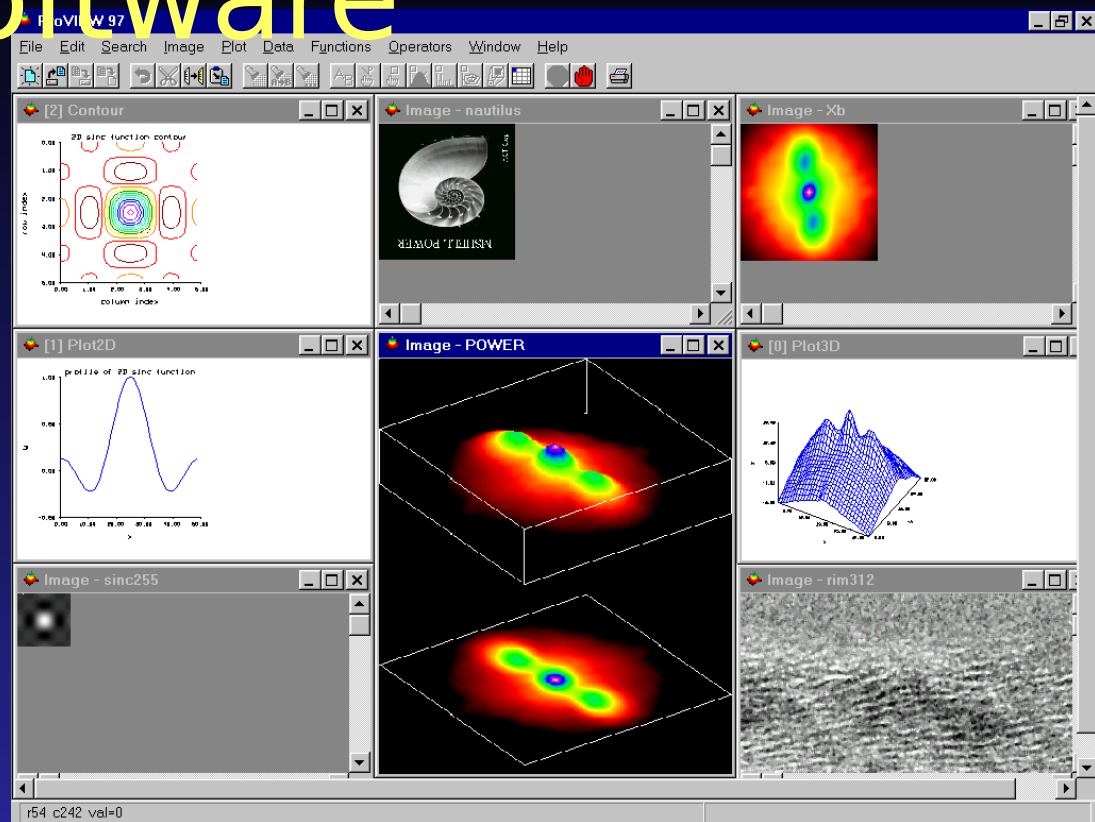
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MSHELL Provides the Computational Engine Used by ProVIEW & WIFE

ProVIEW Provides Many of the Graphical Capabilities Used Under WIFE



NASA/CODMAC Definitions

<http://pds.jpl.nasa.gov/stdref/chap6.htm>

BASED ON THE NATIONAL RESEARCH COUNCIL

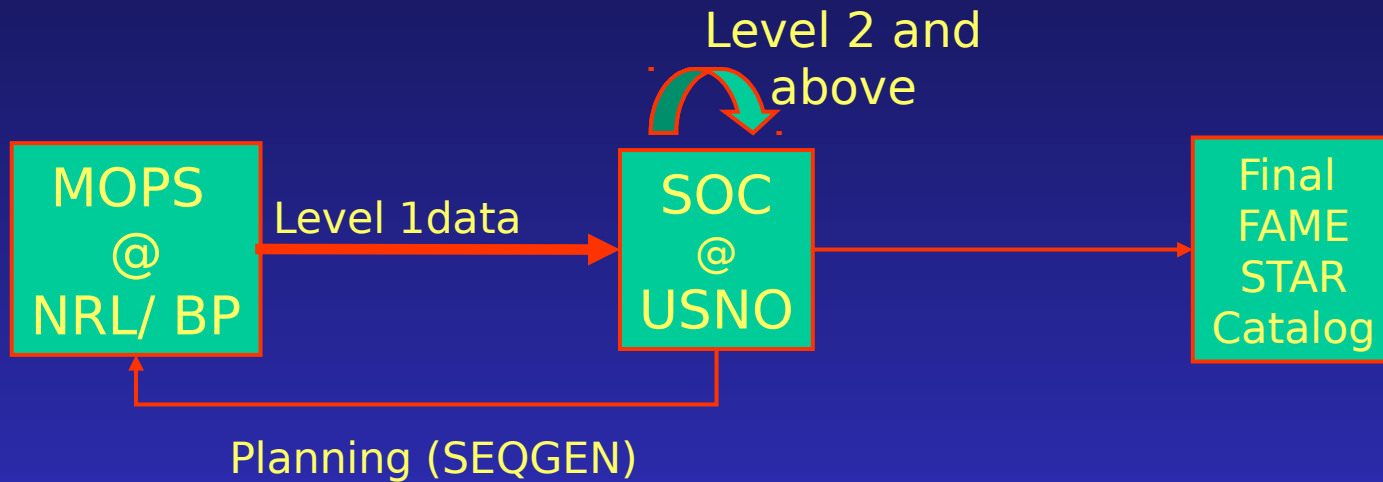
COMMITTEE ON DATA MANAGEMENT AND COMPUTATION (CODMAC) DATA LEVELS

Level	Proc. Type	Data Processing Level Description
1	Raw Data	Telemetry data with data embedded.
2	Edited Data	Corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experimental Data Record (EDR). Data are also tagged with time and location of acquisition. Corresponds to NASA Level 0 data.
3	Calibrated Data	Edited data that are still in units produced by instrument, but that have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No resampling, so edited data can be reconstructed. NASA Level 1A.
4	Resampled Data	Data that have been resampled in the time or space domains in such a way that the original edited data cannot be reconstructed. Could be calibrated in addition to being resampled. NASA Level 1B.
5	Derived Data	Derived results, as maps, reports, graphics, etc. NASA Levels 2 through 5.
6	Ancillary Data	Non-science data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc.
7	Correlative Data	Other science data needed to interpret space-borne data sets.
8	User Description	Description of why the data were required, any peculiarities associated with the data sets, and enough documentation to allow secondary user to extract information from the data.
N	N	Not Applicable



SOC – Characteristics

- The FAME Science Operation Center (SOC) Is a Facility Located at the USNO
- Developed and Operated by USNO





SOC – Requirements

SOC Has Three Primary Responsibilities

- Operate/Monitor The Instrument
- Operate a First Look and Troubleshooting Stage
 - Data INGESTION PIPELINE (IPL)
- Operate the Data Analysis and Reduction Stage
 - Data ANALYSIS PIPELINE (APL)



SOC – Requirements

- Capture ALL S/C Data Streams Relevant for Instrument Operations and Science Data Analysis
- Archive Data Streams Along With Critical Intermediate Products
- Auto Anomaly Call-out



SOC – Requirements

Operate the On-orbit FAME Observatory Instrument

- Instrument Tasking
- Mission and Instrument Planning

On-orbit Monitoring of the FAME Observatory

- Provide Near Real-time Troubleshooting
- Trigger Recovery Activities in Cooperation With MOC

Provide Near Real-time Analysis of Science Data

- Confirm Stellar Magnitude,
- Monitor Image Quality
- Determine Satellite Attitude



SOC - Data Volume

Expected Pre-flight Data Volume			
TBD Data Volume of instrument data to be collected in the Laboratory			
Expected In-flight Data Volume (binned Stars only)			
			Comment
Mission Duration	5	years	
#of Stars/sec	1000		
unbinned stars/sec	5	sec	13x20 pixels TBD
Bits/Star	336		1x20 pixels
Data Volume/sec	42	KBytes	after stripping from CCSDS package
Data Volume/day	3.6288	GBytes	← manageable volume!
Data Volume/Month	110.376	GBytes	
Data Volume/year	1.324512	TBytes	
Data Volume over Mission	6.62256	TBytes	

Note: Each Star Will Be Observed an Average of 1000 times



RECOMMENDATIONS

MO &- DA

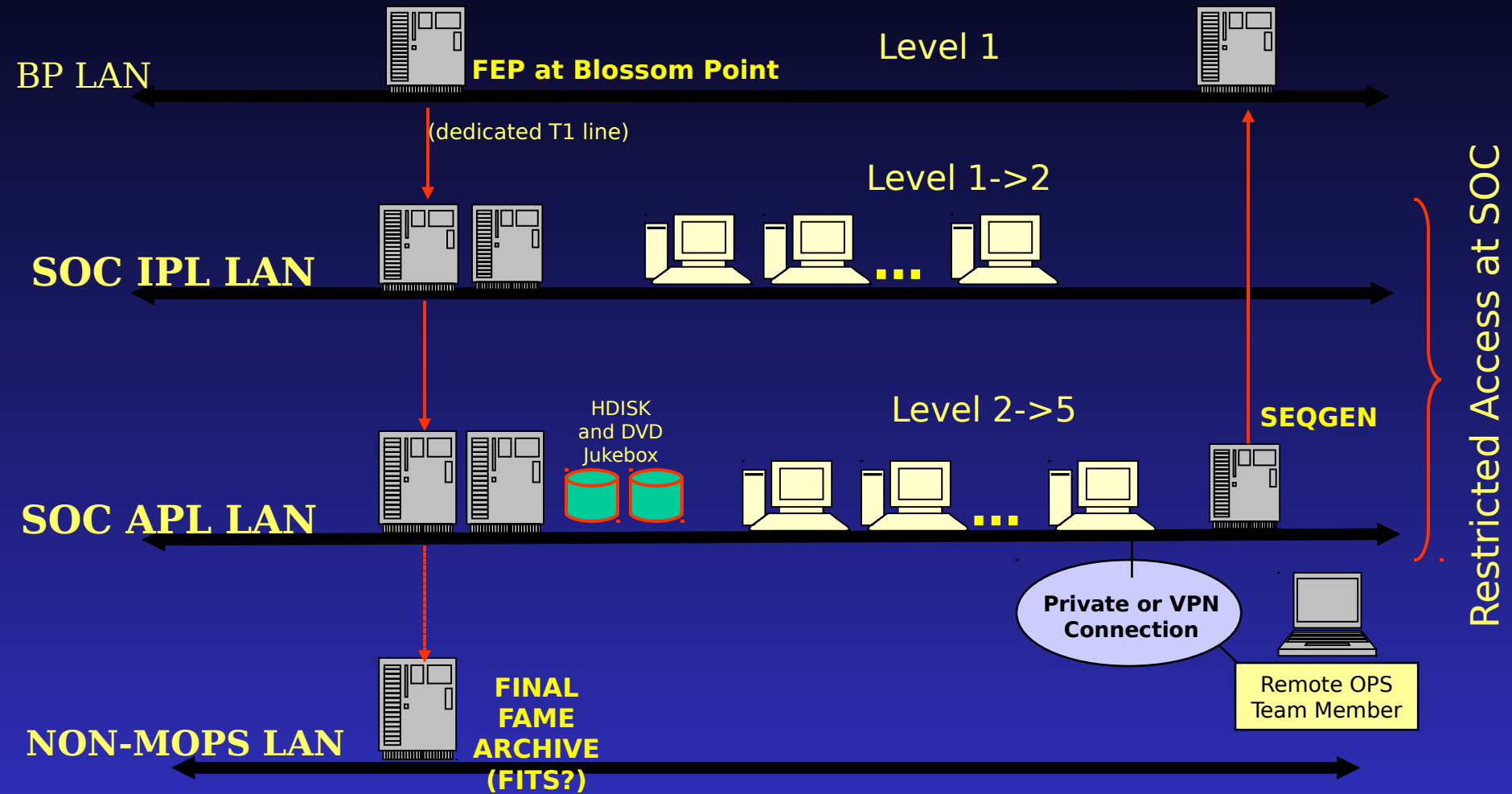


SOC PIPELINE

- PIPELINE is the name given to the actual FAME HW/SW configuration at the SOC
- ACT recommends two PIPELINE stages that operate on different networks and timings:
 - Data Ingestion PIPELINE (IPL)
 - Data Analysis PIPELINE (APL)



SOC Network Topology



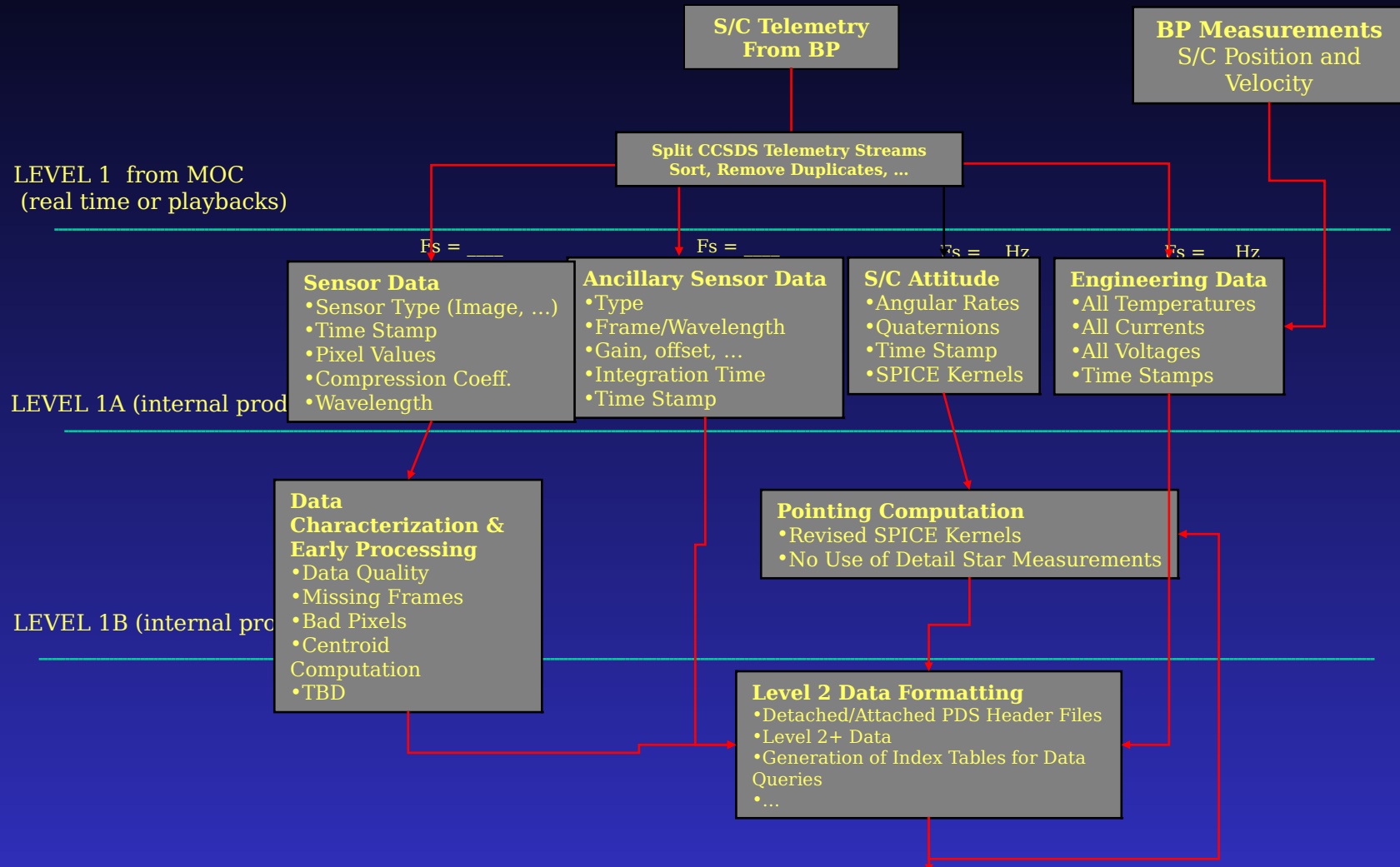


SOC Ingestion PIPE-LINE

- *Expected Data Volume*
- *Role*
- *Data Flow Diagram*
- *Functional Requirements Diagram*
- *Data Products at SOC-IPL*
 - *List of Products*
 - *Formats*



DATA FLOW DIAGRAM (CCSDS → Level 2 Archive)





Ingestion PIPELINE Role

- Ingest up to 4 GBytes/Day (Including Derived Products)
- Produces up to 4x10 GBytes/Day?
 - Output Of this stage is For Internal Use
 - Internal Format Most Facilitate:
 - » MOPS Support
 - » Data Analysis
- Output Goes into The Online Archive Server
- Assess Data Integrity
- Deliver Quality Acknowledgment to MOPS Team
 - Provide Online Conversion to Other Formats, E.G., PDS, FITS, NetCDF, TIFF, HDF, ...



Ingestion PIPELINE Role

- Archive and Keep ALL Data and Products Online for Rapid Access
- Planning Support to Science Operations Team Members
 - Planning/analysis Tools Jointly Developed by MOPS and SOC
 - Sc. Sequence Planning Done by SOC Staff on a Regular Basis
 - Evaluation of Celestial Sphere Mapping Coverage at All Times
 - Sc. Operations Team Will Incorporate Changes Into Planning Depending on Previous Performance
- Products and Data Access
 - Facilitate Data Access to Mission Operations Support Staff and Sc. Operations Team Members
 - Generation of High Fidelity Maps Using S/C Provided Ephemeris and Quaternions
 - Provide Annotated Color Output Copy for Selected Images/plots
 - Hard Copies (for Internal Use), Digital Formats, Video Segments
 - Generation of High Level Products in Response to WWW Requests (Internal Use Only)



SOC-IPL

Derived Functional Requirements

Pre-Formatting Stage (CCSDS →EDR)

- Remove Duplicates and Clean Data as needed
- Merge Ancillary Data With Sensor Data
- Create Archive Files and Direct Structure

Spacecraft Pointing

- Update/Revise **SPICE** Kernels
- Update Spacecraft Pointing Files from Star data
- Perform FOV Projections
- Pointing Stability vs. Time
- Use Control Stars (as needed)

Support Sensor Characterization vs. Time (for each CCD)

- Non-Uniformity Matrices
- Gain Corrections and Bad Pixels
- Dark Field Matrices
- Point Spread Function
- LED response and Charge Response vs. TIME
- **Flag ill-performance conditions**

Sequence Planning

- Support Sc. Steering Comm.
- Provide Instrument Seq. for Mission P. Group

Continuous Quick Look Updates

- Real-Time Display of Raw Data, grids+histog.
- Perform Early Projections Onto Celest. Sphere
Using SPICE Kernel(s), SatVIEW, Cat. Know.
- Generate single CCC Solution for Validation

Continuous Format and Archival Update

- Includes Cal. Matrices
- Include Derived Geometric Information
- Flag Existence of Any Known System Noise
- Create Backups
- Validation of Products

Archived Data Access + High Level Prod.

- Support for Local and WWW Access
- Query Database (TOI, ROI, CCD/Sensor)
- Rapid Access to query results
- Remote Execution of Algorithms
- Test Calibration for Selected Data
- Latest Calibration Version will be On-line
- Support Generation of High Level Products by DA



SOC Analysis PIPELINE (SOC-APL)



- Expected Data Volume → 7Tbytes X ?
- Role →
- Data Analysis Scheme
 - Derived Requirements, ...
- Data Products at SOC-APL
 - List of Products
 - Data Formats → FITS, PDS, ...




Data Formats

Planetary Data System Home - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Search Favorites History

Address <http://pds.jpl.nasa.gov/> Go Links Radio



Welcome to the Planetary Data System

Home Scientists Public Data Producers Educators Related Sites Help

The Planetary Data System (PDS) archives and distributes scientific data from NASA planetary missions, astronomical observations, and laboratory measurements. The PDS is sponsored by NASA's Office of Space Science. Its purpose is to ensure the long-term usability of NASA data and to stimulate advanced research. Learn more about [PDS](#). Additional information is also available in the [PDS Annual Report](#).

FOR SCIENTISTS

This is where you can find science data and documentation archived in PDS.

FOR THE PUBLIC

This is the place to go for dazzling images and information about NASA's planetary missions.

FOR DATA PRODUCERS

This section provides the tools and information you need to archive data in the PDS.

FOR EDUCATORS

This link takes you to our educational resources.

Internet

Keyword: FITS - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Search Favorites History

Address <http://navigation.helper.realname.com/frame1/1/262/default.asp?realname=FITS&url=http%3A%2F%2Fpds.jpl.nasa.gov/> Go Links Radio

You reached this site by typing **Keyword: FITS** in the Internet Explorer address bar. [Learn more about Keywords](#)

FITS - Flexible Image Transport System

For Users
HEASoft
XANADU
FTOOLS
tv
XSTAR
Calibration

For Developers
FITS
FITSIO
Data Standards
CalDB

SITE SEARCH

FITS stands for 'Flexible Image Transport System' and is the data format most commonly used within astronomy. FITS is much more than just another image format (such as jpg or gif) and is primarily designed to store scientific data sets consisting of multidimensional arrays (1-D spectra, 2-D images or 3-D data cubes) and 2-dimensional tables containing rows and columns of data. Further information about the definition of FITS formats is available [here](#).

The [HEASARC](#) has played a leading role in developing standard conventions for the format for different types of data files and in developing software for analyzing FITS files, especially within the domain of high energy astrophysics. The following FITS resources are provided by the HEASARC:

Software

- [FITSIO](#) - a set of library routines for reading and writing FITS files from within C and Fortran programs.

Internet



PIPELINE

High Level Requirements

- Adaptable to Different OS and HW platforms
- Allow easy incorporation of Custom Algorithms
- Provide Autonomous Functionality → Cost Savings



SOC Server Requirements

- Multiple Data Bases are Required !!!
- Data Base Schemes
 - RDBMS
 - ODBMS (OOP and File Structures)
 - Flat Files
- Production Software Development Environment Absolutely Needed
 - Multiple Options Are Available
 - High Level Languages → Good for Matrix Algebra
e.g., IDL, Matlab, MTOOL++, C++ w/ Templates
 - 'C' good for portability and Speed



SOC Data Access Requirements

- Access to raw data
- Access to derived products
- Access from LAN or WAN to Authorized Users
- Ability to query by TOI, ROI, SOI
- Ability to spatially register (mosaic) different observations
- Ability to apply your own algorithms
- Ability to download in your preferred format(s)
- Ability to look at all data in a common denominator
- Ability to subset the data any way you like!
- Get access to data in a minimum amount of time
- Ability to Monitor Sensor Performance
- Good Network Connectivity and utilization of



Candidate PIPELINE Architectures

- 100% Done In-House By USNO
 - ➔ High Risk (FAME DA is fairly complex) ➔ More Labor
- 100% COTS
 - ➔ Not Possible, FAME needs Customization
- Mixture COTS and Custom
 - ➔ Best Approach for RDMBS Tools (COTS) [performance]
 - ➔ Job Scheduling and Tracking (COTS)
 - ➔ Standard Procedures ➔ Custom
 - ➔ Expandable by In-house Built Algorithms



PIPE as FAME's PIPELINE

- Planetary Image Processing Environment
 - PIPE is a Custom Version of WIPE
<http://wipecentral.net>
 - Tailored for Space Missions
 - Built-In Development Environment (ProVIEW)
 - Built in PDS Parsers
 - PIPE/SatVIEW ↔ JPL/SPICE Interface
 - Built-in ODBC
 - Works in Windows 2000 → can be ported to UNIX



Existing Critical WIPE Users

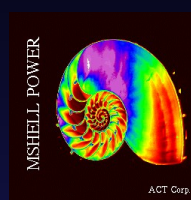
- **CNO-N096**
 - **SACLANT CENTER (Rapid Environ. Assessment)**
 - **NRL's Naval Center for Space Technology**
 - **NAVO (Mine-Warfare)**
 - **NRL Stennis (Data Exchange Interface)**
 - **NOAA/NESDIS (Coast Watch / Alaska SAR DEMO)**
 - **NASA**
 - **APL (Global Mapping of Mercury)**
 - **SPAWAR (JWID- METOC Flight Planner Tool)**
 - **NOAA/NCDDC (National Coastal Data Dev.Center)**
- =====
- **WIPECENTRAL.NET (ACT's commercial data portal)**
 - **Commercial Remote Sensing Data Providers...**
 - **UPRM (X-band Ground-Station)**

T
M
E

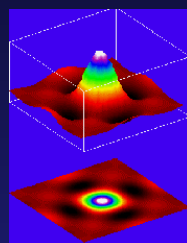
NOTE: ALL REGISTERED USERS OF WIPE CAN HAVE ACCESS TO ALL NEW INGESTION/SERVING MODU



PIPE LEVERAGES IN WIPE



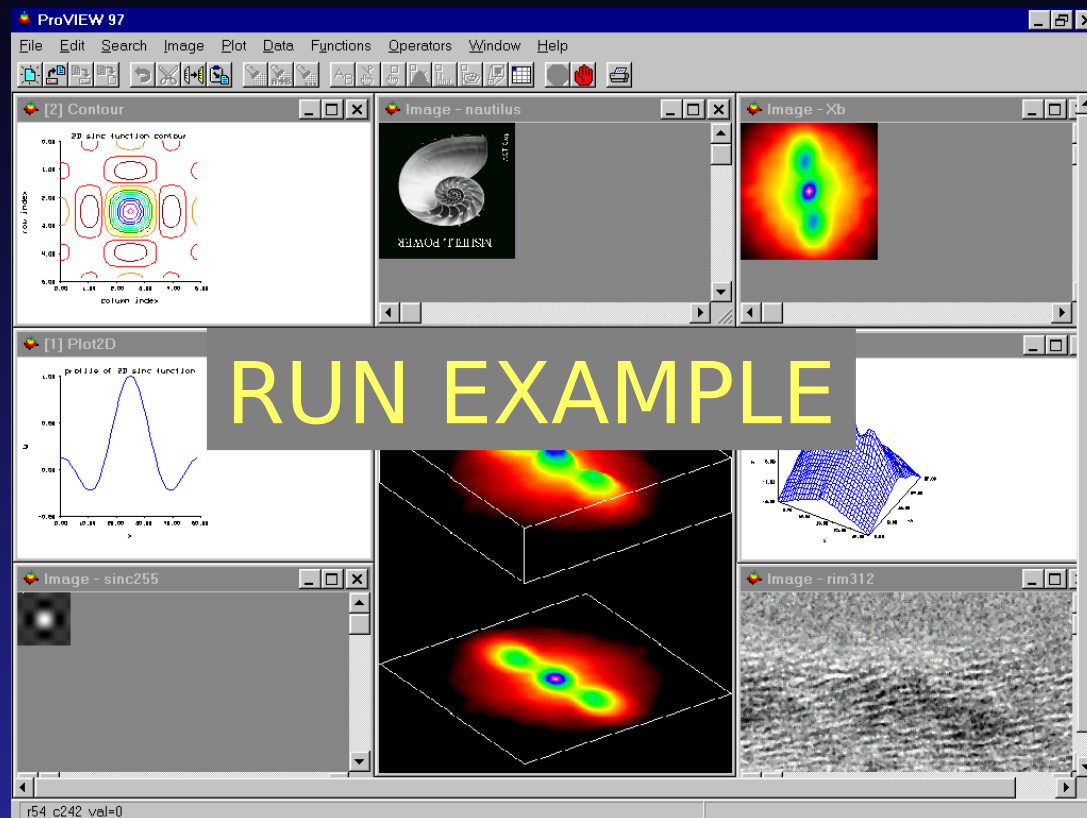
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MSHELL Provides the Computational Engine Used by ProVIEW & WIPE

ProVIEW Provides Many of the Graphical Capabilities Used Under WIPE



WWW



Image Processing Environment

WIPE is a Network Centric Architecture For Geo-Spatial Data:

- Assimilation,
- Processing,
- Distribution,
- Discovery,
- Fusion



DATA WAREHOUSE

• WIPE provides Flexible Network Access to all Data in an

Interactive Manner ==> Products and Virtual Products

- Form and Distribute Products
- Merge for Value Added

• Client Side Software Requirements: Netscape or



Algorithms Implementation

- Ability to Incorporate Algorithms Provided by Sc. Team (If Desired)
 - *ANSI C Code (Preferred Choice) , C++ next option*
 - FORTRAN Code
 - User Provided DLL
 - Stand Alone Application - Command Line Driven
 - IDL/ENVI or ProVIEW Script File (Uses High Level Syntax)
- Complete Documentation Is Required to Include Custom Algorithms:
 - Mathematical Formulation
 - All Required Inputs Specified + Estimates of Computational Requirements
- Version Control is done via VisualSourceSafe



ProVIEW / MSHELL - Features

- Algebraic and matrix operations with a mathematically intuitive syntax (MATLAB, IDL like)
- Powerful MACRO scripting language with support to relational operators and flow control
- Floating-point image processing computations for high accuracy, and support for both complex and real numbers
- Over 400 operators
 - FFT, convolution, edge detection, etc



ProVIEW - Features

- Geometric operations allowing to resize and rotate images using unequal horizontal and vertical scaling
- Satellite Imagery Map Projection
- A flexible display of multiple images, plots, and scripts
- Contrast processing such as linear stretching and intensity range re-mapping
- Capability for each image to have its own pseudo color look-up tables with as many colors as the hardware permits



ProVIEW - Features

- Interactive 2D, 3D, and contour plots
- Support for multiple image formats
 - ASCII, 8bits/pix, floating point, and key industry standard formats such as TIFF, JPEG, BMP, FITS, PGM, PPM, GIF, and PDS, FITS
- Optimum use of full dynamic range of display hardware
- Support for text attributes that are attached to an image
 - store an image header
 - processing instructions to be applied to an image

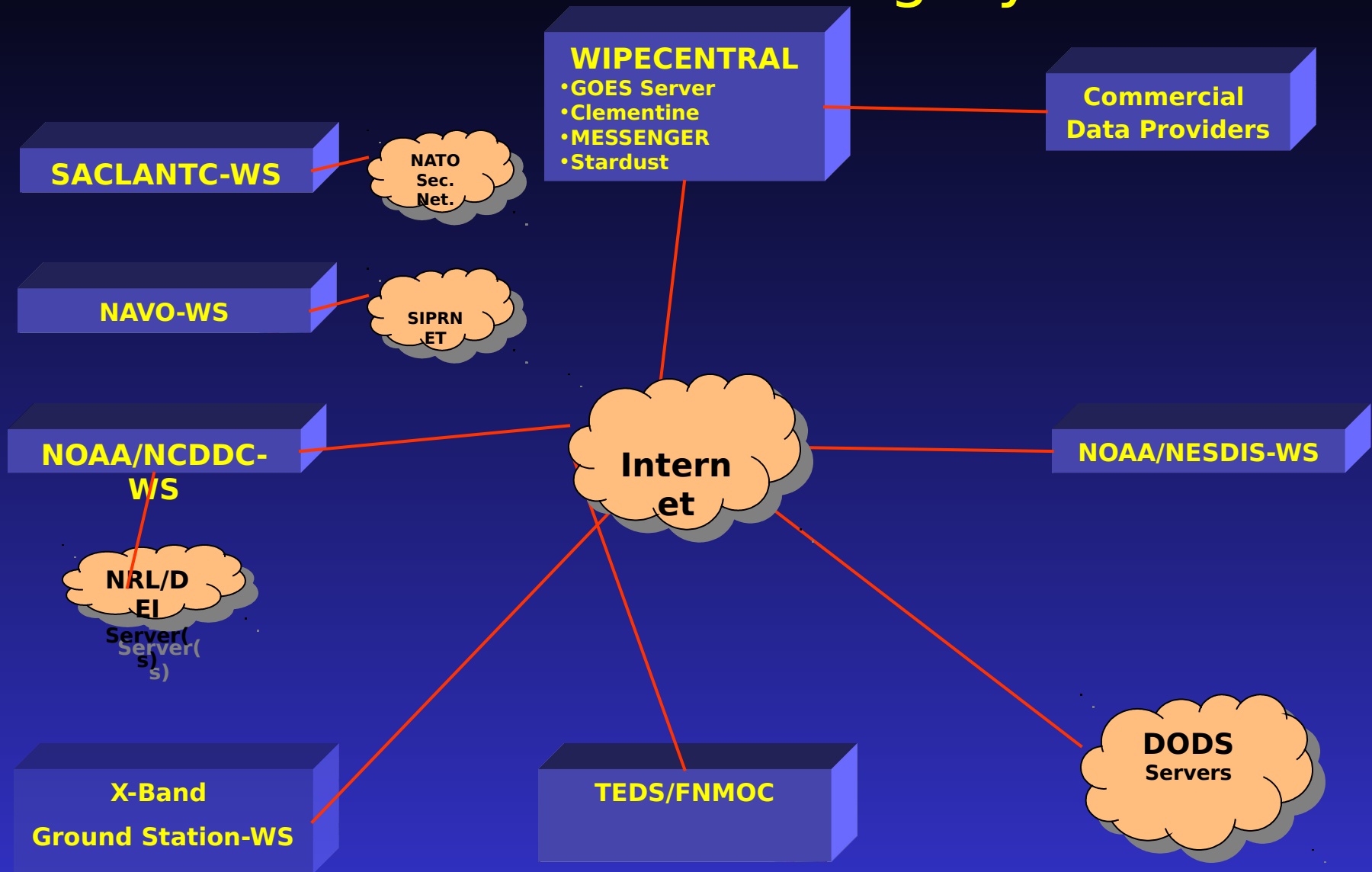


ProVIEW - Features

- Ability to call your own DLL functions
- Ability to have virtual image variables, which can be as large as your collective disk space
- Easy access to hyper spectral data
- Ability to generate GIF video sequences within the interpreter, ideal for HTML browsers
- Data Base Interconnectivity via ODBC
- Built-In XML Parser

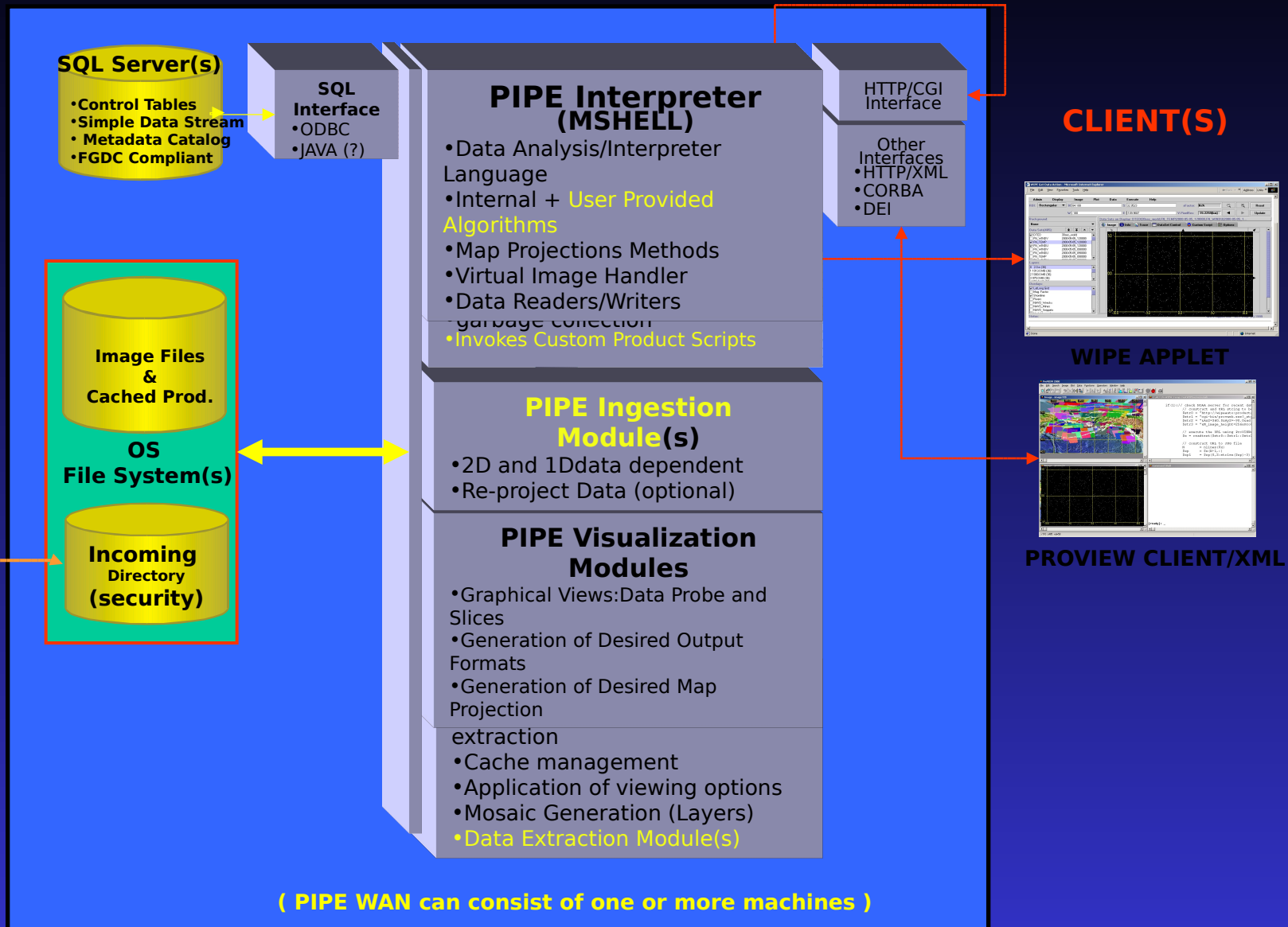


Example of WIPE Servers Associated with Satellite Imagery





Proposed PIPE Architecture





PIPE's Data Types, and Models

Input Data Types:

- Point Data
- Vector Data
- Image Blobs
- Gridded Data
- Non-gridded Data
- Volumetric Data
- Volumetric and Temporal Data
- *Video-Streams!*

Support to Key Data Standards :

- CEOS (Radarsat, ...)
- Vector Product Format
- Shapefile
- Geo-Tiff, and JIFF (Joint Metoc Viewer Image File Format)
- NetCDF
- ASCII Tables
- SQL Relational Data Bases PDS (NASA) and FITS
- WMO GRIB Format
- XML
- ...



Example Star Catalog Browser



WIPE Get Data Action - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Search Favorites History Address Links Radio

WIPE Dynamic and Static Geo-Spatial Databases

WIPE Data Browser

Preferences Legend Download SensorView Info Animation Image Help

Back Forward Zoom out Zoom in Reset

Update

ROI: Box N 21.1142 S 6.955 xFactor: 0.5650
W -28.415 E -0.0966 V.PixelRes: 6.1569(km)

Background: None

Data Sets on Display: SAO_StarCatalog|all magnitudes

Image URL Info Server messages DataSet Control Custom Script Options

Data Sets(3):

- ☒ SAO_StarCatalog all magnitudes
- ☐ SAO_StarCatalog mag 10 and below
- ☐ SAO_StarCatalog mag 5 and below

Layers:

0

Overlays:

- ☒ LatLong Grid

Status: WIPE Applet 20010223 - ACT Corp. (c) 2001

http://www.actgate.com/wipe Internet



Example Star Catalog Browser



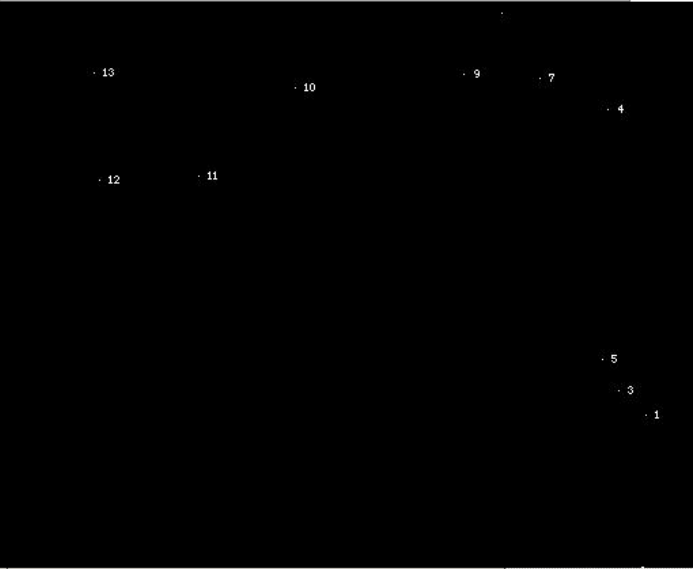
ProVIEW Web Results - Microsoft Internet Explorer

Star View of NAVCAM Camera

Right Ascension(deg)	Declination(deg)	Roll
-14.26	14.03	0

CCD Cols(pixels)	CCD Rows(pixels)	Focal Length(m)
512	512	202e-3

Pixelsize	Visual Magnitude Threshold
12e-6	9



Done Internet

FAME StarCamera View - Microsoft Internet Explorer

WIPE Dynamic and Static Geo-Spatial Databases

Camera: FAME

Camera Orientation

Right Ascension (deg) -14.26 Declination (deg) 14.03

Roll 0

Camera Parameters

CCD Field of View - Columns (pixels) 2048 CCD Field of View - Rows (pixels) 4096

Focal Length (meters) 15 Pixelsize (meters) 15e-6

Visual Magnitude Threshold 9 Display Options: star index and info table

Submit Reset

Done Internet

ProVIEW Web Results - Microsoft Internet Explorer

i	SAO#	magnitude	(ra,dec)	(row,col)
0	108315	8.4000	(-15.0817, 13.4104)	(437,490)
1	108316	7.8000	(-15.0310, 13.8623)	(304,475)
2	108318	8.9000	(-14.9889, 13.4699)	(419,463)
3	108321	7.9000	(-14.9601, 13.9249)	(286,455)
4	108322	8.9000	(-14.9369, 14.6280)	(79,447)
5	108325	8.0000	(-14.9194, 14.0008)	(263,443)
6	108327	7.2000	(-14.8649, 13.4686)	(420,428)
7	108331	8.7000	(-14.7592, 14.7052)	(56,397)
8	108334	7.5000	(-14.6616, 14.8705)	(8,369)
9	108340	8.3000	(-14.5635, 14.7190)	(53,341)
10	108365	8.9000	(-14.1249, 14.6850)	(63,217)
11	108377	8.7000	(-13.8760, 14.4629)	(128,146)
12	108390	8.1000	(-13.6199, 14.4522)	(131,73)
13	108393	8.8000	(-13.6054, 14.7216)	(52,69)

Note: Displaying Information for the first 300 s

Done Internet



Monitoring Temporal Trends of Key Calibration Variables

Clementine: Camera Parameters Used and Calibr... - Microsoft Internet Explorer

File Edit View Go Favorites Help

Back Forward Stop Refresh Home Search Favorites Print Font Mail

Address <http://www.actgate.com/act/clemcal/smallmaps/> Links

TEST-BED for LOW RESOLUTION MOSAICs and CALIBRATION

Select the Clementine Camera for which you are interested in seeing, in the form of a map of lat. & long., the different variables that affect the calibration of either a single image or extended mosaics. For example, this testbed allows you to visualize how the gain values for the UVVIS camera were changing over either the 1st, 2nd, or both months of lunar mapping.

Clementine Cameras

uvvis DATA: Inputs for Analysis

Select task to be performed or image to be viewed

- ☐ gain image
- ☐ integration time image
- ☐ offset image
- ☒ FPA temperature image
- ☐ cryocooler temperature
- ☐ cryocooler on time
- ☐ solar distance
- ☒ solar phase angle
- ☐ incidence angle
- ☐ frame number/orbit
- ☐ emission image
- ☐ compression ratio image
- ☐ calibrated image

Month = 1; // use 1, 2, or 3 (both months)
\$filters="a" // use desired filter letter
\$camera="uvvis"
lutn = 2; // 0=normal gray scale, 1=color map1

Submit

uvvis FPA Temperature image for Filter=a

(10^0) X

row 0 =	3.00-	0.00i
row 1 =	7.00-	0.00i
row 2 =	10.00-	0.00i

[Click here to download raw data](#)



Concluding Remarks

- FAME's Data Volume/day is Reasonable
- SOC Challenge → Analysis Stage
- For FAME, PIPE Provides Extensible and Scalable Architecture
 - Two PIPE Servers (ingestion and analysis)
- ACT is Ready to Support FAME with the PIPELINE Implementation → HW/SW/Staffing